Prediction of PM, SO_2 & NO_X - GLC'S from Point Source Emissions Using Air Modeling

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Abstract— Air quality assessment by integrating measurement techniques and modeling tools is a crucial element in pollution mitigation. The air modeling tools are routinely used in the environmental impact assessments, risk analysis, emergency planning, and source apportionment studies. Recent strategies for air pollution control in industries have largely neglected the emission reduction measures which are the prime polluting sources. To accomplish this, various air dispersion models have been developed and used worldwide so far for different applications under different scenarios. The Gaussian plume model is a standard approach for studying the transport of pollutants due to turbulent diffusion and advection by the wind. Applications of such models have been made mandatory. It has therefore assumed greater importance for the academicians, consultants and regulatory authorities.

In this study, the AERMOD (the American Meteorological Society/Environmental Protection Agency Regulatory Model Improvement Committee's Dispersion Model, version 7.0.3 Gaussian dispersion models selected to predict the ground level concentrations (GLC's) of Particulate Matter (PM) $\mu g/m^3$, sulphur dioxide (SO_2) $\mu g/m^3$, and oxides of nitrogen (NOx)- $\mu g/m^3$ from point source emissions will be investigated in the study area (10 Km buffer) from the periphery of the industrial area chosen for case study.

In point source emissions, the stacks are subjected to plume rise which again is dependent on force of buoyancy and momentum. The higher is the plume rise or stack, the lesser will be ground level concentrations (GLC's).The emissions when released into the atmosphere are subjected to transportation, dispersion, transformation, and fall out and wash out and finally reach the ground level at a particular distance and concentrations.

The relationship between the source of emissions and its magnitude with the ground level concentrations (GLC's) at receptor points is governed by air dispersion models which take into the account by the source strength, plume rise, atmospheric stability, mixing height, wind velocity, terrain and other meteorological conditions.

The comparison between the predicted and field sampled downwind concentrations for PM, SO_2 & NO_X ($\mu g/m^3$) will be carried out in this study to predict the average downwind ground level concentrations (GLC's).

Index Terms— AERMOD, downwind, Gaussian plume model, ground level concentrations (GLC's),PM, point source emissions, receptor points, NO_X, SO_2.

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1 INTRODUCTION

AIR pollution has long been recognized as a brain storming issue worldwide. The onset of technological and scientific innovations in various fields and diverse activities of human race for its elegance have put extra load on the atmosphere by way of releasing air pollutants like particulate matter (PM10, PM2.5), sulphur dioxide (SO2), oxides of nitrogen (NOx), carbon monoxide (CO), unburned hydrocarbon (HC), hydrogen fluoride (HF) and other organic as well as inorganic pollutants including trace metals responsible for causing health consequences[1]. Entry of pollutants into the atmosphere occurs in the form of gases or particles. Continuous mixing, transformation and trans-boundary transportation of air pollutants make air quality of a locality unpredictable. The growth of population, industry and number of vehicles and improper implementation of stringent emission standards make the problem of air pollution still worse. According to WHO estimates, 4-8 per cent of deaths occurring in the world are related to air pollution, whereas a 2005 estimate from WHO indicates that air pollution in major Southeast Asian and Chinese cities ranks among the worst in the world and contributes to the deaths of about 500,000 people annually[2]. Rapid industrialization and vehicular traffic especially in the urban areas of India is a great threat to air quality. Emissions from industrial stacks are one of the major sources of air pollution in recent epoch [3]. Dispersion estimates are determined by using distribution equations and/or air quality models. Gaussian plume equation is simple and widely used to identify the variation of pollutant concentrations away from the centre of the plume. This distribution equation determines ground level pollutant concentrations based on time-averaged atmospheric variables (e.g. temperature, wind speed).One of the Dispersion Model developed base on Gaussian plume equation was AERMOD (The American Meteorology Society-Environmental Protection Agency Regulatory Model) which is recommended for air quality simulations by the US EPA (2005).These models stand for the state-of-the-science in air quality modeling and provide powerful features to simulate various modeling situations and considerations.

2 METHODOLOGY

2.1 Study Area

Proposed site is a rural region which falls under tumkur district of Karnataka state. It is chiefly elevated land. This region has emerged as a hub to industrial advancement. This industrial area is located at

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about 20 Km from Tumkur and 70-75 km from Bangalore. Project Site is situated adjacent to NH 4.

2.2 Meteorological Data

AERMOD model requires hourly surface data values for wind speed, wind direction, temperature, relative humidity and cloud cover. Both data files for the surface and profile files were then used to generate the meteorological file required by the AERMOD dispersion model using the AERMET meteorological pre-processor programme. This AERMET programme has three stages to process the data. The first stage extracts meteorological data and assesses data quality through a series of quality assessment checks. The second stage merges all data available for 24-hour periods and writes these data together in a single intermediate file. The third and final stage reads the merged meteorological data and estimates the necessary boundary layer parameters for dispersion calculations by AERMOD.

Table 1:- Frequency Distribution for post-monsoon season (0-24 Hours)

Year	Hour	Avg. Wind speed	Wind Direction	RH	Temperature	Cloud Cove
		m/s	Degrees	%	K	Oktas
2012	1	1.35	139.03	72.06	17.36	4.15
2012	2	1.58	124.68	79.71	17.84	4.15
2012	3	1.97	123.39	79.71	19.67	4.15
2012	4	2.26	117.10	79.71	21.68	4.15
2012	5	2.32	153.39	81.52	23.48	4.15
2012	6	2.06	105.16	81.52	24.97	4.15
2012	7	2.32	159.52	81.52	25.91	4.15
2012	8	2.58	172.10	74.23	26.28	4.15
2012	9	1.90	150.81	74.23	26.54	4.15
2012	10	2.00	125.65	74.23	26.65	4.15
2012	11	1.90	152.10	44.97	26.12	4.15
2012	12	1.52	135.32	44.97	24.79	4.15
2012	13	1.26	139.19	44.97	22.81	4.15
2012	14	1.42	132.74	33.74	21.95	4.15
2012	15	1.74	147.10	33.74	21.41	4.15
2012	16	1.90	125.32	33.74	20.74	4.15
2012	17	1.87	129.03	37.55	20.09	4.15
2012	18	1.87	135.48	37.55	19.57	4.15
2012	19	1.87	123.55	37.55	19.13	4.15
2012	20	1.87	131.77	58.16	18.81	4.15
2012	21	1.68	127.26	58.16	18.46	4.15
2012	22	1.74	134.84	58.16	18.22	4.15
2012	23	1.52	131.61	72.35	17.86	4.15
2012	24	1.48	140.97	72.35	17.70	4.15

The meteorological pre-processed data was used to determine its corresponding Wind Rose plot. The Wind rose shows the most predominant wind direction blows from which the wind blows. This means that the emissions plume will be dispersed mainly in that direction. The wind speed and direction for post-monsoon season year 2012 were recorded on continuous basis during study period at proposed site location. The percentage frequencies of occurrence of various wind speed classes in different directions were computed from recorded data on 24 hourly bases and presented in the form of Wind Rose plot (see Figure 1). The wind rose diagram shows the predominant winds are mainly flowing from East, with the secondary wind direction being from the West. Calm conditions are observed for 10.78% of the total time. The wind data were further analyzed to obtain predominant wind direction and average wind speed for 0 to 24 hrs and the same data were used in prediction of impacts on air environment.

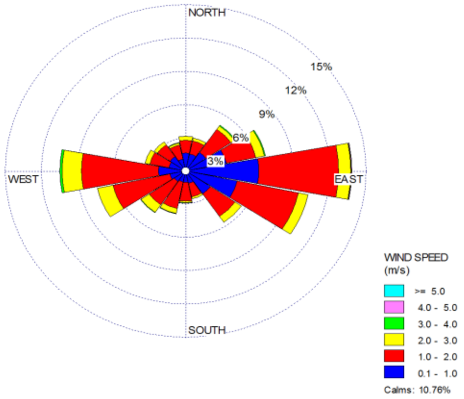


Fig.1.Wind rose of the meteorological station in the study domain for the Post Monsoon Season

The estimation and evaluation of atmospheric emissions from proposed activity involves a number of scientific inputs. Emissions from each activity vary from one another greatly with respect to characteristics and quantity of emissions; controlling factors. The screening models were used for designing the Ambient Air Quality Monitoring Network and the monitoring stations were selected based on the occurrence of maximum pollutant concentrations under expected micro meteorological conditions during study period of post-monsoon season and other criteria as described earlier.

Table 2:-DG SET Stack details

S.NO	Input Parameters	Units	FUEL TYPE BSII
1	Diesel Generator Capacity	Kva	2500
2	Fuel Consumption(l/h) 100% Load	l/h	528
3	Stack Height	m	13
4	Diameter of Stack	m	0.75
5	Number of stacks	No	10
6	Gas Exit velocity	m/s	20
7	Gas Exit Temperature	K	403
8	Density of Diesel	Kg/m3	820
9	Gas Exit Flow Rate	m3/s	8.8
Emission rates			
1	PM	0.0002g/s	
2	SO2	0.08g/s	
3	NOX	1.9 g/s	

2.3 Emission Sources

The emission sources are mainly the diesel generator set (DG SET). Their details are as given below.

2.4 AERMOD Dispersion Modeling

Hill height scales as well as terrain elevations for all receptor locations AERMOD View dispersion model was developed by Lakes Environmental software. It is used extensively to assess pollution concentration and deposition from a wide variety of sources. It is a regulatory steady-state plume modeling system with three separate components: AERMOD View (AERMOD Dispersion Model), AERMAP (AERMOD Terrain Pre-processor), and AERMET (AERMOD Meteorological Pre-processor). The AERMOD model includes a wide range of options for modeling air quality impacts of pollution sources. Some of the modeling capabilities of AERMOD include the following:

- The model is used to analyze primary pollutants.
- Source emission rates can be treated as constant or may be varied by month, season, hour-of-day, or other optional periods of variation. These variable emission rate factors may be specified for a single source or for a group of sources. For this project all emission rates were treated as constant.
- The model can account for the effects of aerodynamic downwash due to buildings that are nearby point source emissions.
- Receptor locations are specified as gridded and/or discrete receptors in a Cartesian or polar coordinate system.
- Site location involving elevated terrain,the AERMAP terrain pre-processing program is incorporated into the model to gene ate.
- The model contains algorithms for modeling the effects of settling and removal (through dry and wet deposition) of large particulates and for modeling the effects of precipitation scavenging for gases or particulates.
- AERMOD requires two types of meteorological data files, a file containing surface scalar parameters and a file containing vertical profiles. These two files are provided by AERMET meteorological pre-processor programme.

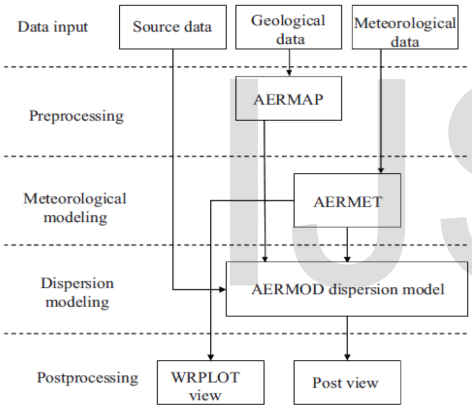
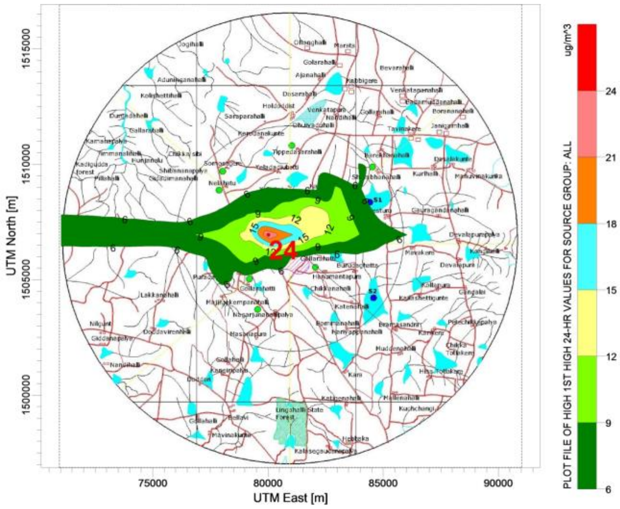


Fig. 2.Data flow in the AERMOD modeling



•Maximum concentration = 24µg/m^{3} at 1770m in West Direction
•Contour Interval = 3

Fig.3.Predicted 24 Hourly Average GLC of NO_X (µg/m^{3}) for DG Set

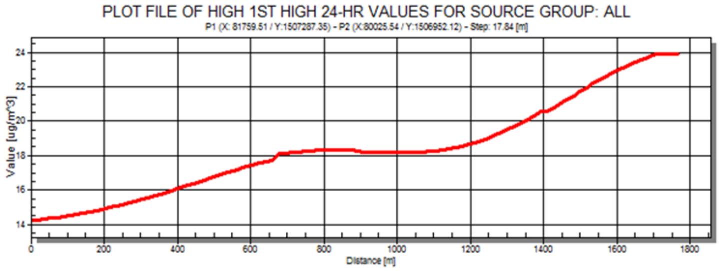
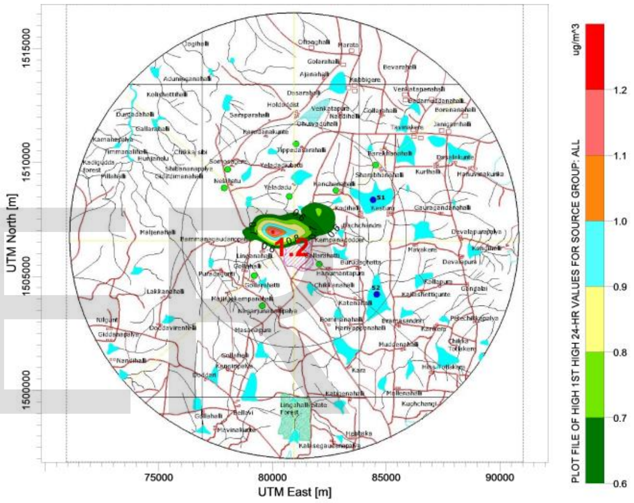


Fig.4.NO_X Plot file of 1st high 24 hour values for source group all

3 RESULTS AND DISCUSSIONS

3.1 Predicted GLC for NO_X

The graph is plotted against the Concentration Vs Distance, where the minimum pollutant concentration was less than 14 µg/m^{3} and while for a period of time the concentration has increased from 14µg/m^{3} to 24µg/m^{3} at 1770m and hence the highest concentration is predicted as 24 µg/m^{3} at 1770m distance.



•Maximum concentration = 1.2µg/m^{3} at 1770m in West Direction
•Contour Interval = 0.1

Fig.5.Predicted 24 Hourly Average GLC of SO_2 (µg/m^{3}) for DG Set

3.2 Predicted GLC for SO_2

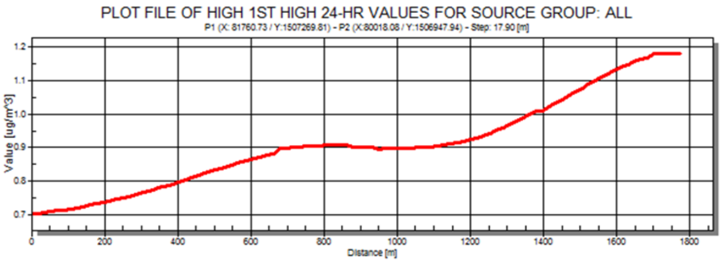
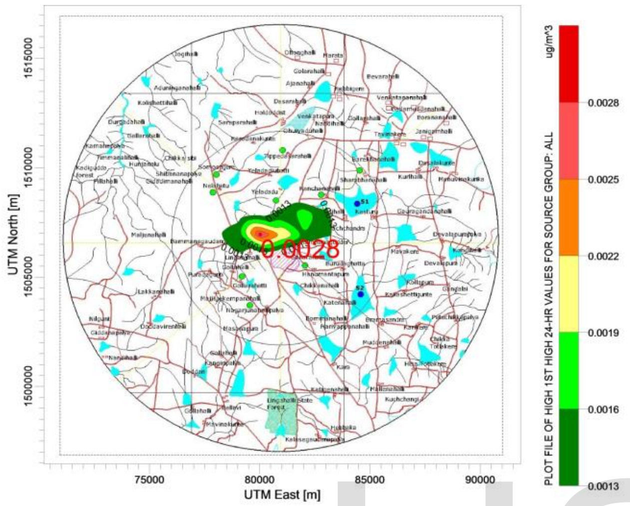


Fig.6.SO_2 Plot file of 1st high 24 hour values for source group all

The minimum pollutant concentration was less than 0.70 µg/m^3 and while for a period of time the concentration has increased from 0.70µg/m^3 to 1.2µg/m^3 at 1770m and hence the highest concentration is predicted as 1.2 µg/m^3 at 1770m distance.

3.3 Predicted GLC for PM



•Maximum concentration = 0.0028 µg/m^3 at 1770m in West Direction
•Contour Interval = 0.0003

Fig.7.Predicted 24 Hourly Average GLC of PM (µg/m^3) for DG Set

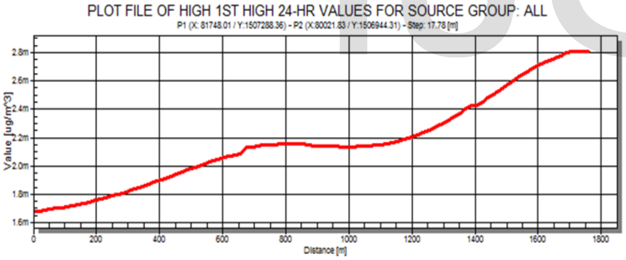


Fig.8.PM Plot file of 1st high 24 hour values for source group all

The minimum pollutant concentration was less than 1.6 µg/m^3 and while for a period of time the concentration has increased from 0.6 µg/m^3 to 0.0028 µg/m^3 at 1770m and hence the highest concentration is predicted as 0.0028 µg/m^3 at 1770m distance.

Table 3 summarizes the maximum predicted concentrations for the proposed study area and their comparison with the National Ambient Air Quality Standards-Central Pollution Control Board (NAAQS – CPCB (2009)). The results revealed that the maximum predicted ground level concentrations from the proposed sources of the industrial area did not exceed the Significant Impact Concentrations. Additionally, the maximum predicted ground level concentrations from the proposed industrial area sources and the baseline concentrations (as recommended in the Air Quality Guideline Document) were all less than the NAAQS.

4 CONCLUSION

This paper presents predictions of air pollutants (SO_2, NOx and PM) emitted from a proposed industrial area to be constructed 20 km North-North-West of Tumkur District, Karnataka .AERMOD and local meteorological data were used to predicted concentrations of major air pollutants in the vicinity of the project in order to ensure compliance with the Indian standards (CPCB, 2009) for ambient air quality. Our findings indicate that after the implementation of the proposed project, concentrations of air pollutant are found to be well below the permissible CPCB (Central Pollution Control Board) Standards for ambient air quality. Therefore, the proposed activity is not likely to have any significant adverse impact on the air environment in the vicinity of the proposed project. However, the SO_2 concentration is expected to be high due to the NH-4.which is adjacent to the project area. Implementing proper Environmental Management Plan along with mitigation measures like Water sprinklers, and trees planting, around the industrial area can minimize the pollution and protect the environment from the adverse effects.

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Table 3:- Post Project Scenario for Industries

24 – Hourly Concentrations	**Concentrations**		
	SO_2(µg/m^3)	**NO_X (µg/m^3)**	**PM (µg/m^3)**
Baseline Scenario (Max)	24.2	20.1	58.6
Predicted GLC	1.2	24	0.0028
Overall Scenario	25.4	44.1	58.6
Distance (m)	1770	1770	1770
Direction	West	West	West
CPCB limits for rural & residential areas	80	80	100